Modeling the impact of habitat fragmentation in brown trout population dynamics

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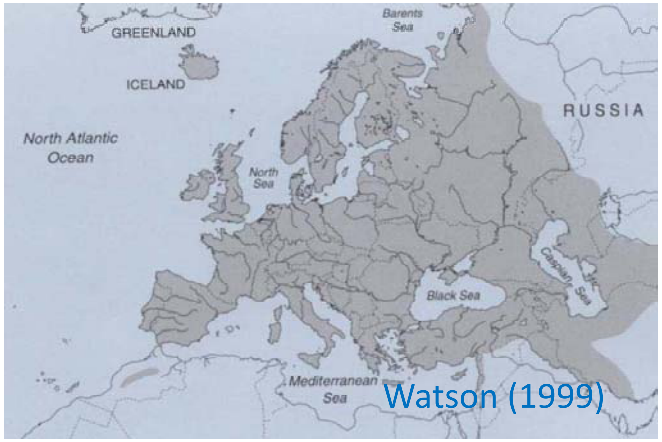
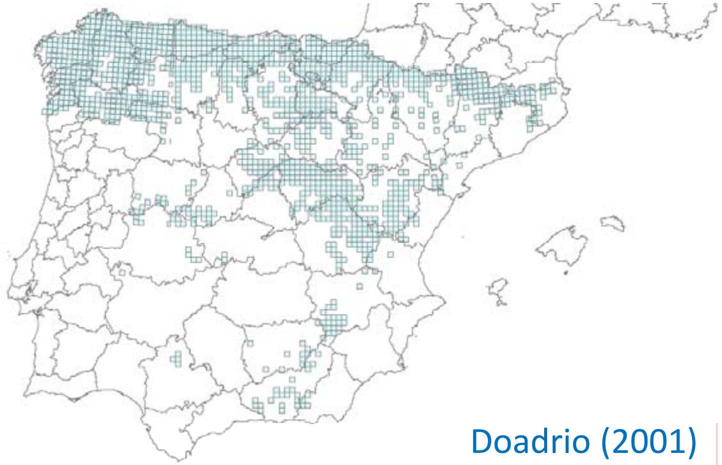
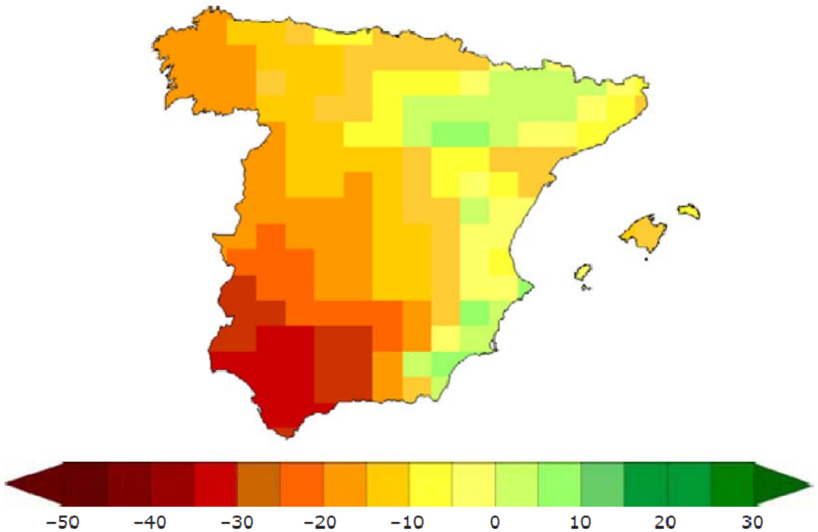
To determine how exogenous and endogenous factors drive the temporal variation of population abundance is a key issue of population ecology.

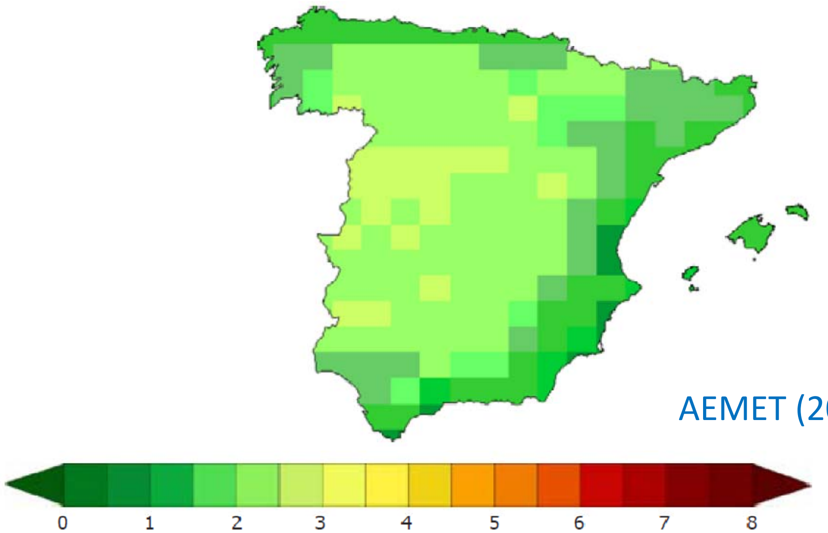


Watson (1999)



Doadrio (2001)





AEMET (2009)

<u>Anual rainfall</u> and **<u>mean temperature</u>**

estimated changes in for the period 2011-2040, compared to the control period (1961-1990).

Population growth rate (*pgr*)

-Its value determines where a species lives and how abundant it is.

- It measures the *per capita* rate of growth of a population.

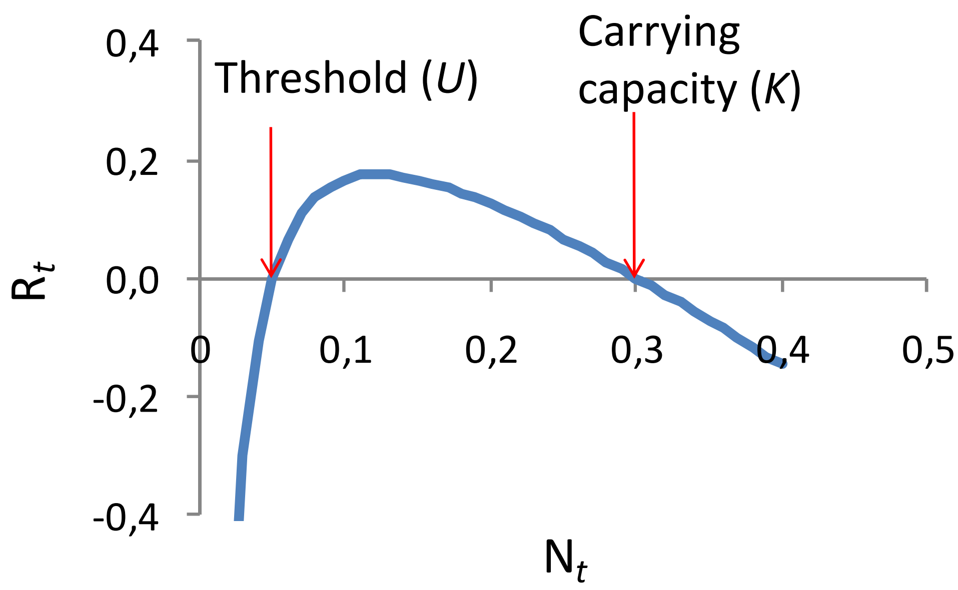
-It tells us whether population size is increasing, stable or decreasing, and indicates how fast it is changing.

$$\lambda_t = \frac{N_{t+d}}{N_t} \Rightarrow \lambda_t = \frac{N_{t+1}}{N_t}$$

$$R_t = \log_e \lambda_t = \log_e \frac{N_{t+d}}{N_t} \Rightarrow R_t = \log_e \frac{N_{t+1}}{N_t} = \log_e N_{t+d} - \log_e N_t$$

Theoretical *R*-function: Theta-logistic with a population threshold size

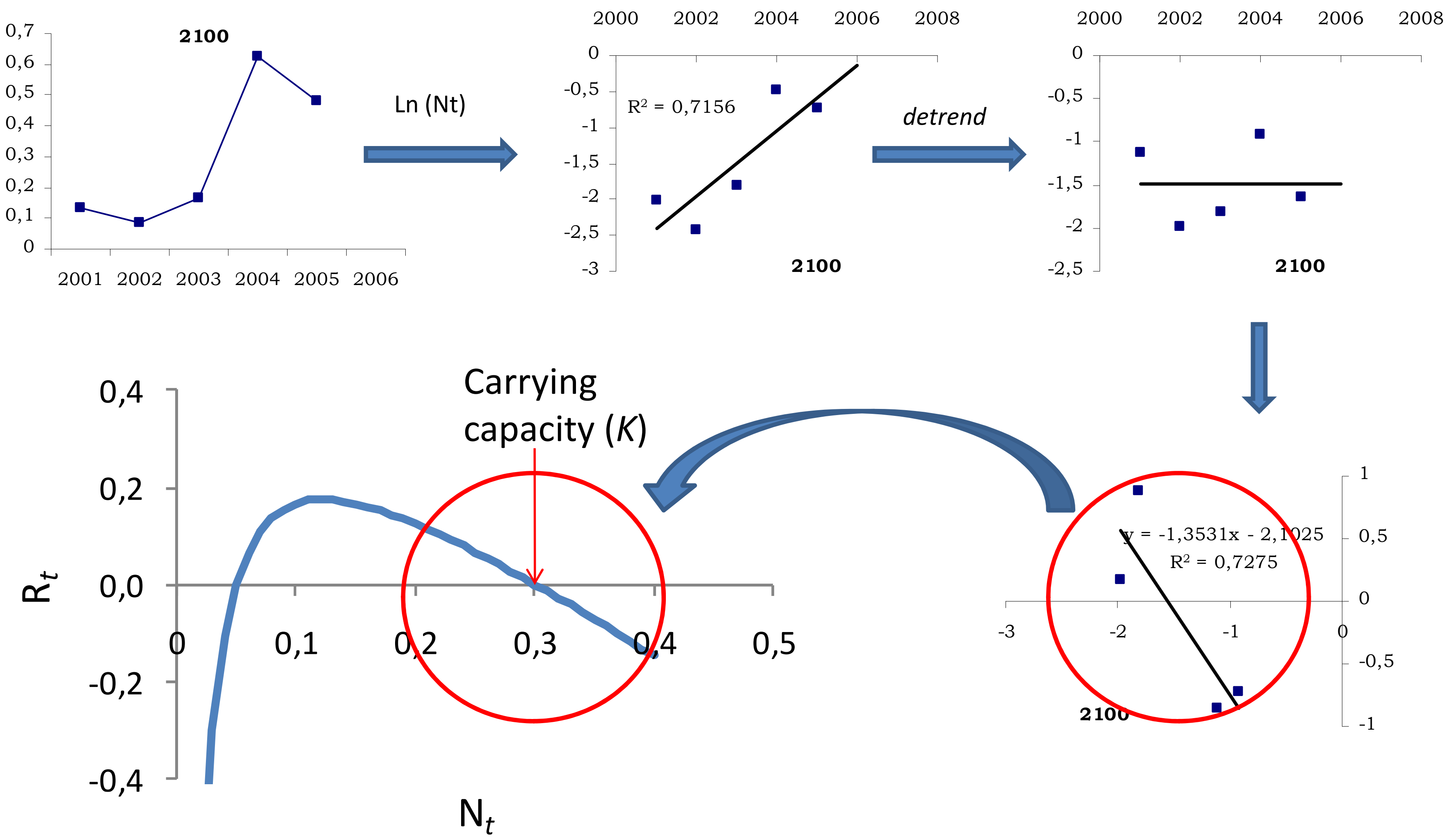
$$R_t = a\left(1 - \frac{N_t}{K}\right) \longrightarrow R_t = a\left(1 - \frac{N_t}{K}\right)^{\theta} \longrightarrow \boxed{R_t = a\left(1 - \frac{U}{N_t}\right)\left(1 - \frac{N_t}{K}\right)^{\theta}}$$



Methods

R-function parameterization

Setting carrying capacity (*K*)

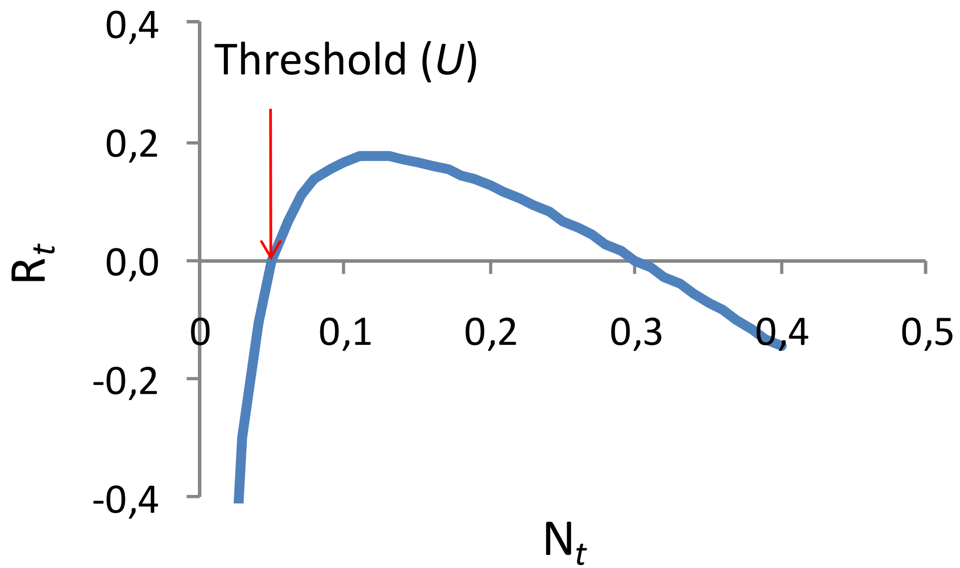


Setting extinction thershold (*U*)

Considering a rough number put forth by Lande (1995, Conservation Biology 9) and Lynch and Lande (1998, Animal Conservation 1). [Although Frankham and Franklin (1996, Conservation Biology 10; 2005, Biological Conservation 1260; 1998, Animal Conservation 1; 1995, 66) think that the number can be lower], (Hilderbrand, personal communication).

Threshold 2,500 fish age 1 and older (Hilderbrand, 2002, North American Journal of Fisheries Management 22) in order to being conservative:

$$U=2{,}500 \text{ adults} \cdot \text{Area}^{-1} = 2{,}500 \text{ adults} \cdot \text{Length}^{-1} \cdot \text{Width}^{-1}$$



Methods

Population growth rate (*pgr*)

The value of *pgr* is influenced by **endogenous (x_i)** and **exogenous (y_i)** factors and its variation can be expressed as a function of those variables (r function):

$$R_t=f(x_{1,t},x_{2,t},\dots x_{n,t},y_{1,t},y_{2,t},\dots y_{m,t}) \longrightarrow R_t=f(x_{1,t},x_{2,t},\dots x_{n,t})+random[s(\lambda_t)]$$

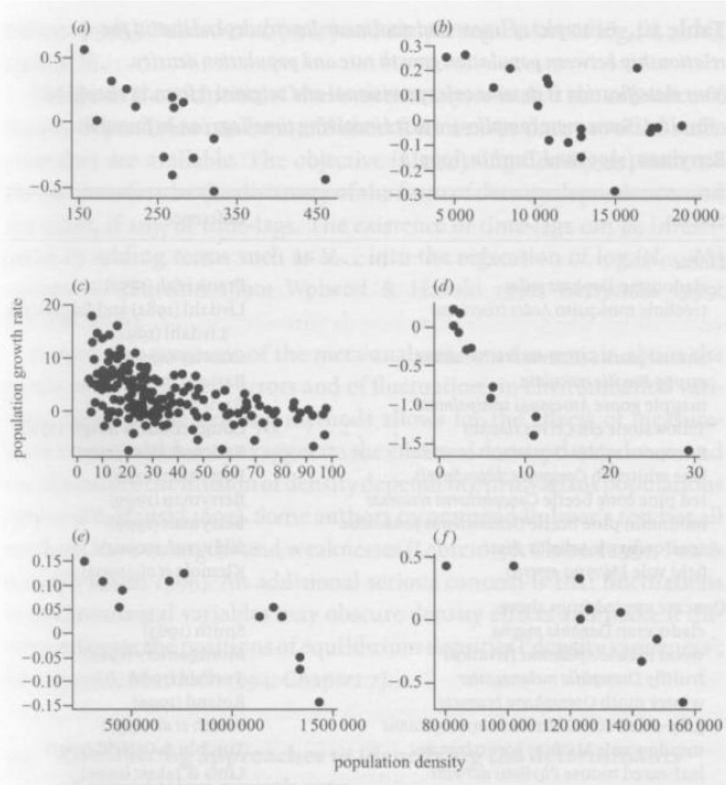


Figure 2.3. Examples of the form of the relationship between population growth rate (r) and population density. Linear relationships in (a) magpie goose and (b) elk; concave viewed from above in (c) meadow vole and (d) arctic ground squirrel; convex viewed from above in (e) wildebeest and (f) sandhill crane. Sources in table 2.1.

Sibly & Hone (2003)

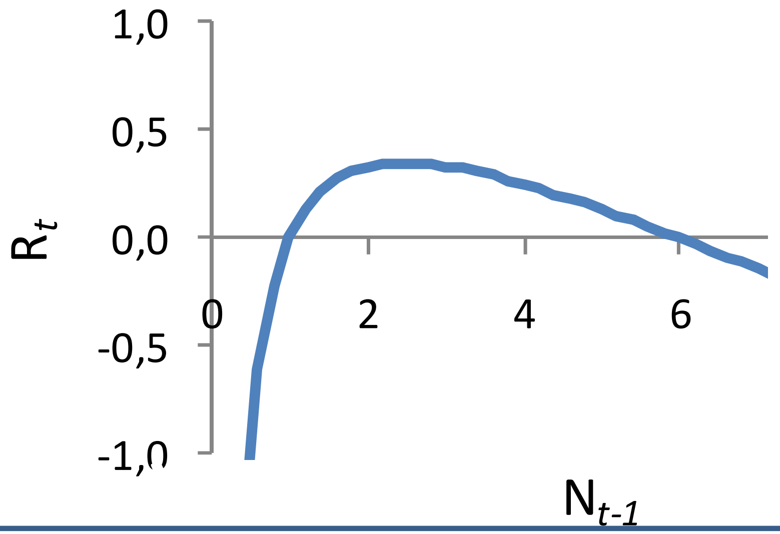
Methods

Population growth rate (*pgr*)

DETERMINISTIC

$\lambda_t = f(x_{1,t}, x_{2,t}, \ldots x_{n,t})$

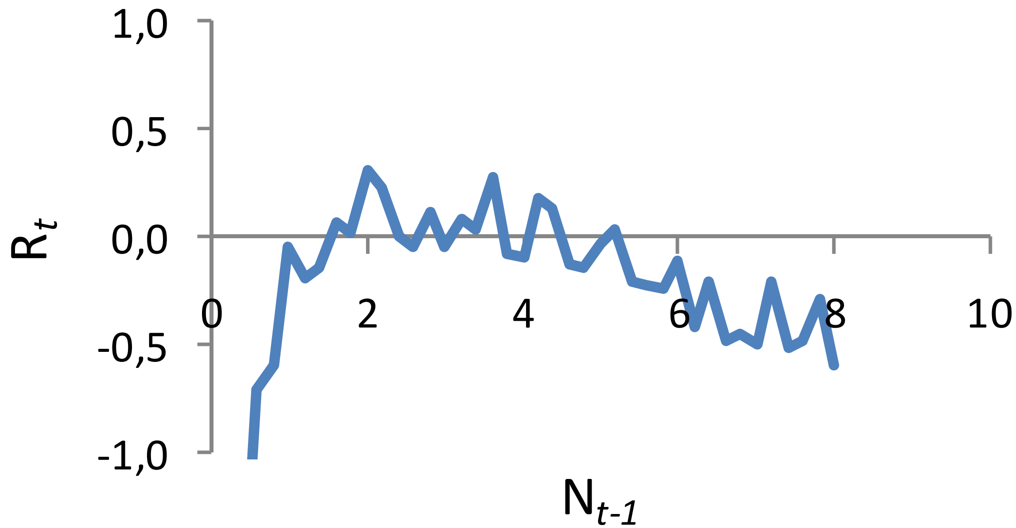
$$R_t = a\left(1 - \frac{U}{N_t}\right)\left(1 - \frac{N_t}{K}\right)^{\theta}$$



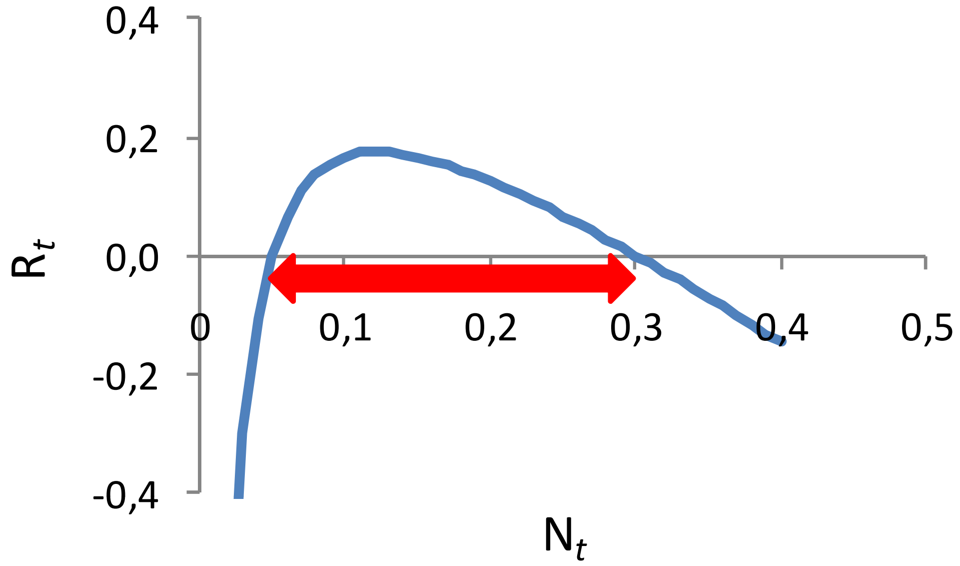
DETERMINISTIC-STOCHASTIC

$\lambda_t = f(x_{1,t}, x_{2,t}, \ldots x_{n,t}) + random[s(\lambda_t)]$

$$R_t = a\left(1 - \frac{U}{N_t}\right)\left(1 - \frac{N_t}{K}\right)^{\theta} \pm Rnd\left(s\left(R_{obs.}\right)\right)$$

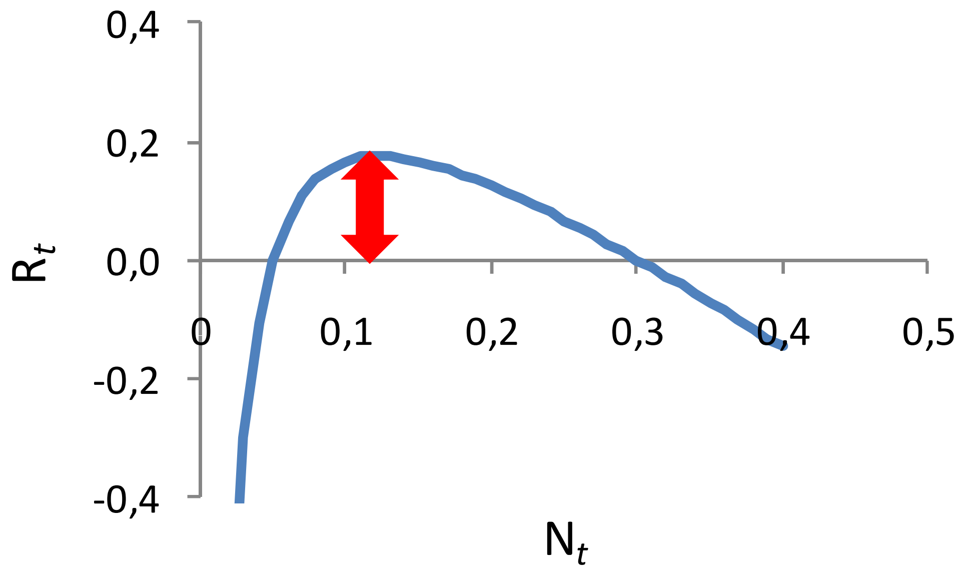


Defining *Resilience*: components



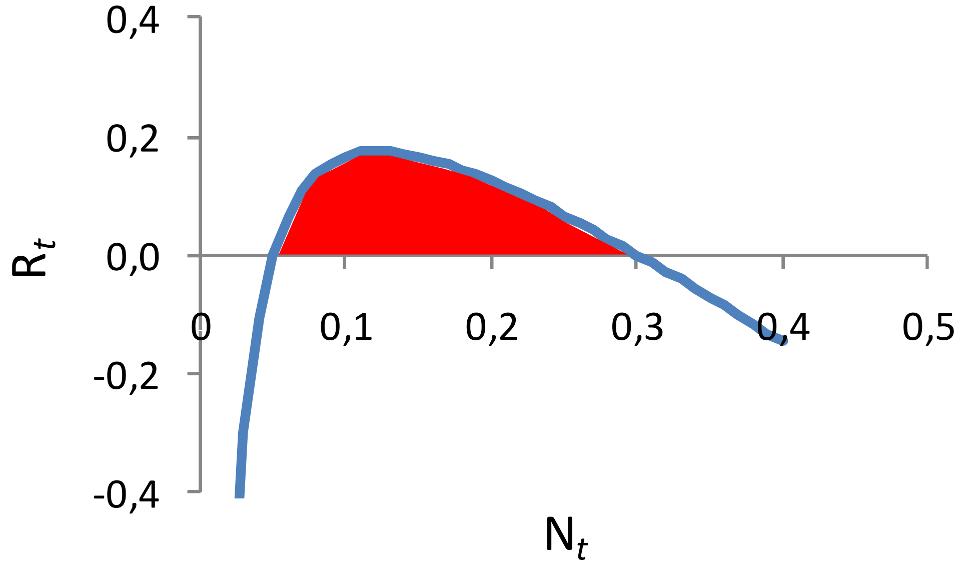
Resistance = Carrying capacity (K) – Extinction threshold (U)

Defining *Resilience*: components



Recovery ability = Maximum population growth rate, $f(a)$

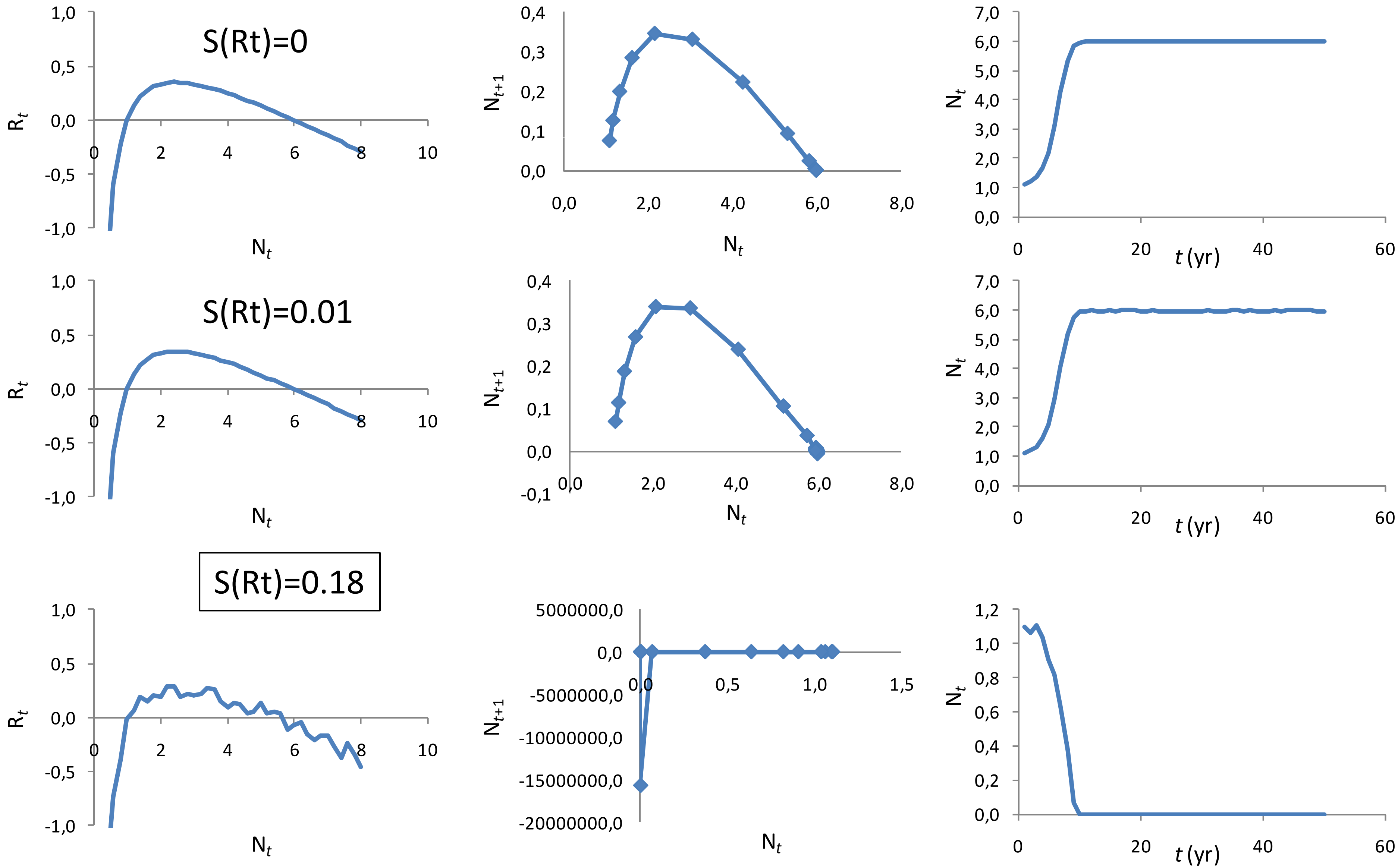
Defining *Resilience* (ρ) value



$$\rho = \int_U^K a\left(1-\frac{U}{N_t}\right)\left(1-\frac{N_t}{K}\right)^{\theta} dN_t$$

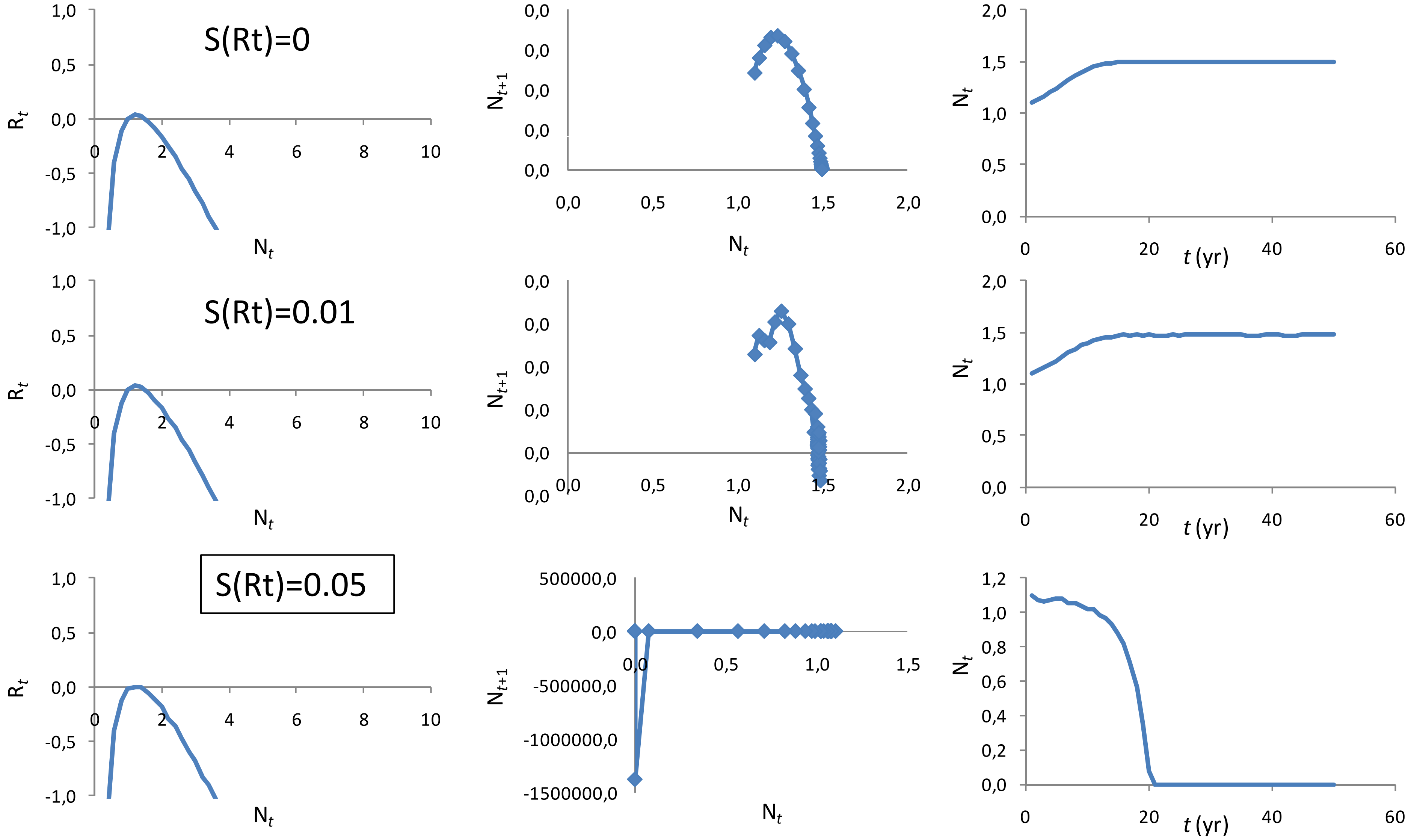
Results

U = 1; K = 6; a = 1 N_0 = U+0.1 = 1.1



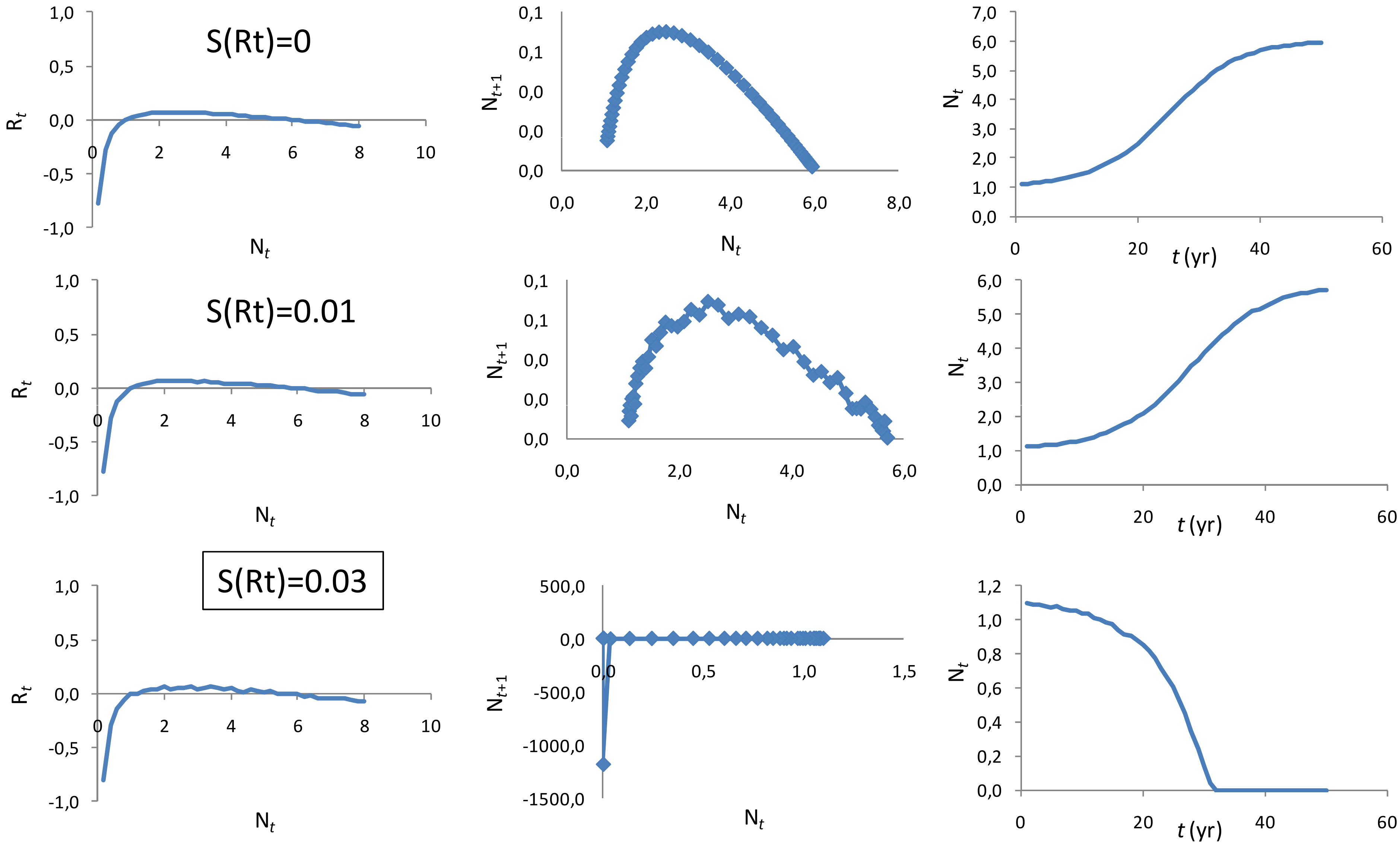
Results

U = 1; **K = 1.5**; a = 1 N_0 = U+0.1 = 1.1



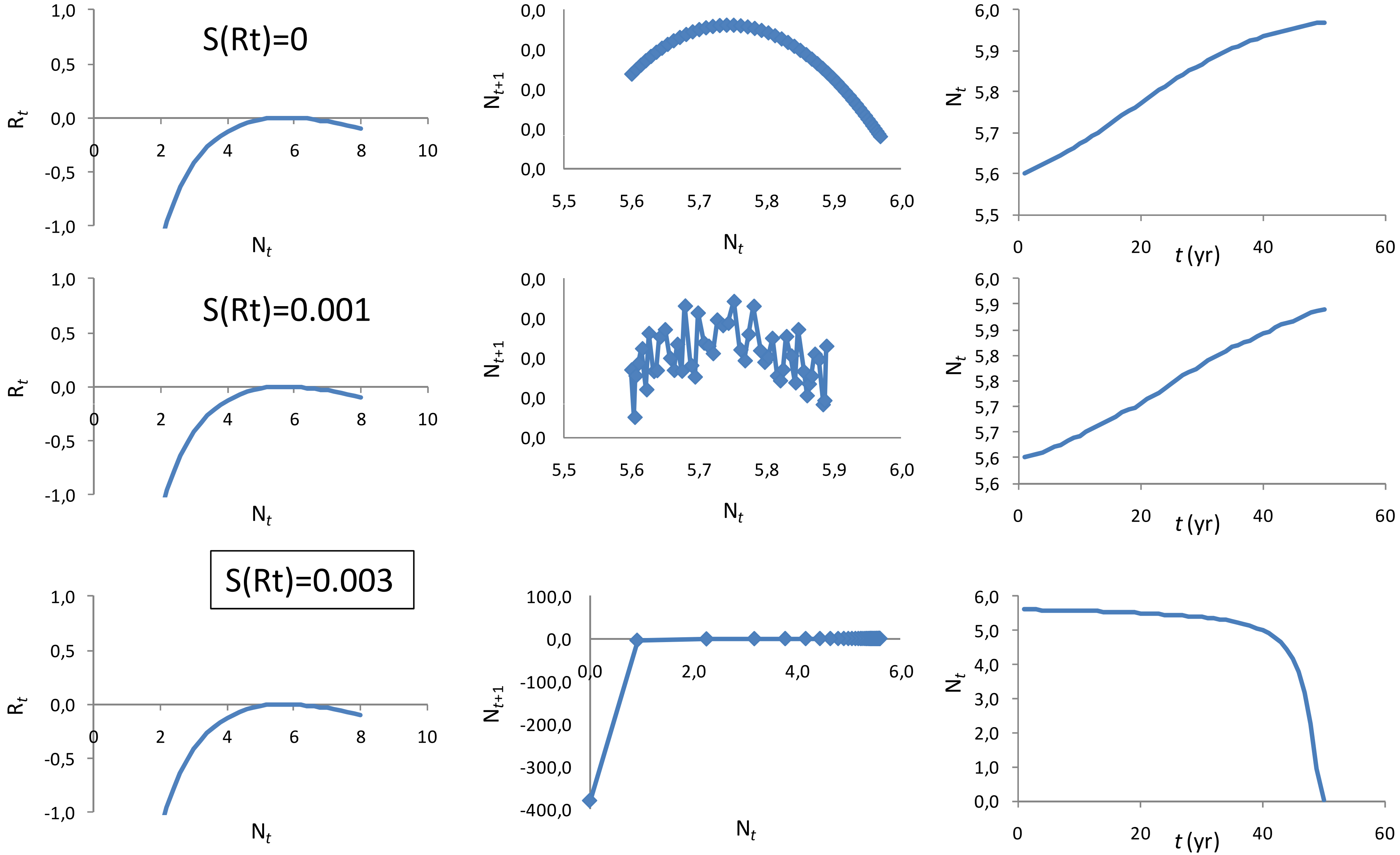
Results

U = 1; K = 6; a = **0.2** N_0 = U+0.1 = 1.1



Results

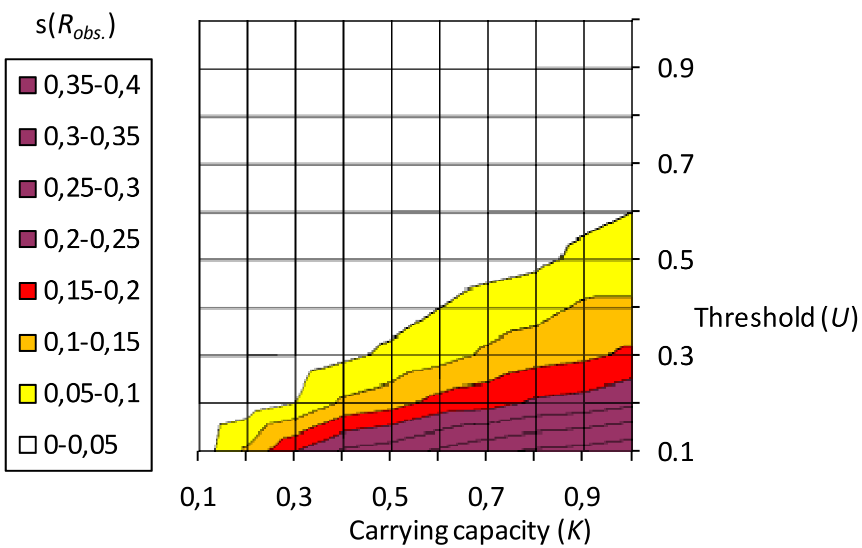
U = 5.5; K = 6; a = 1 N_0 = U+0.1 = 5.6



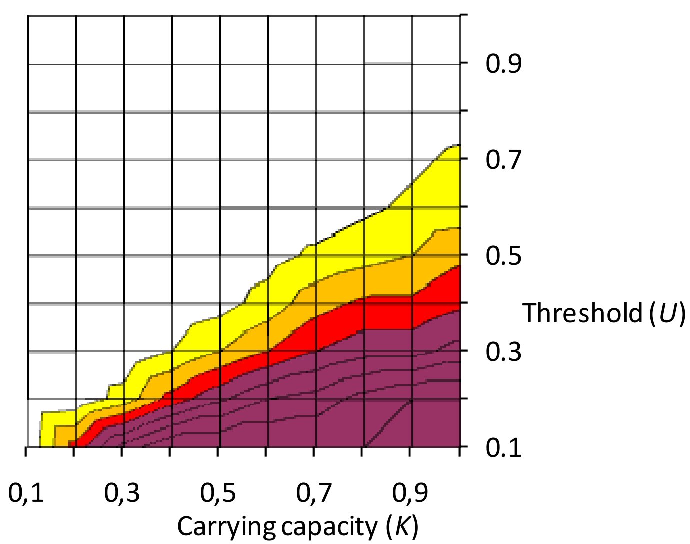
Results

Model sensitivity

a=0.5

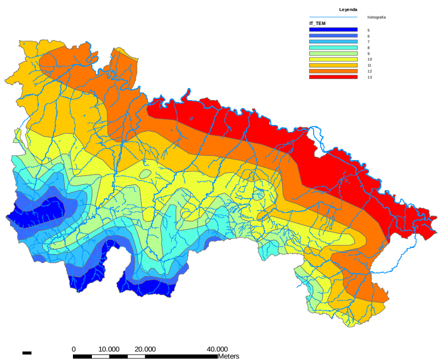


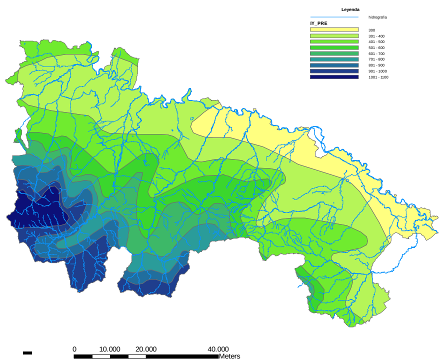
a=1

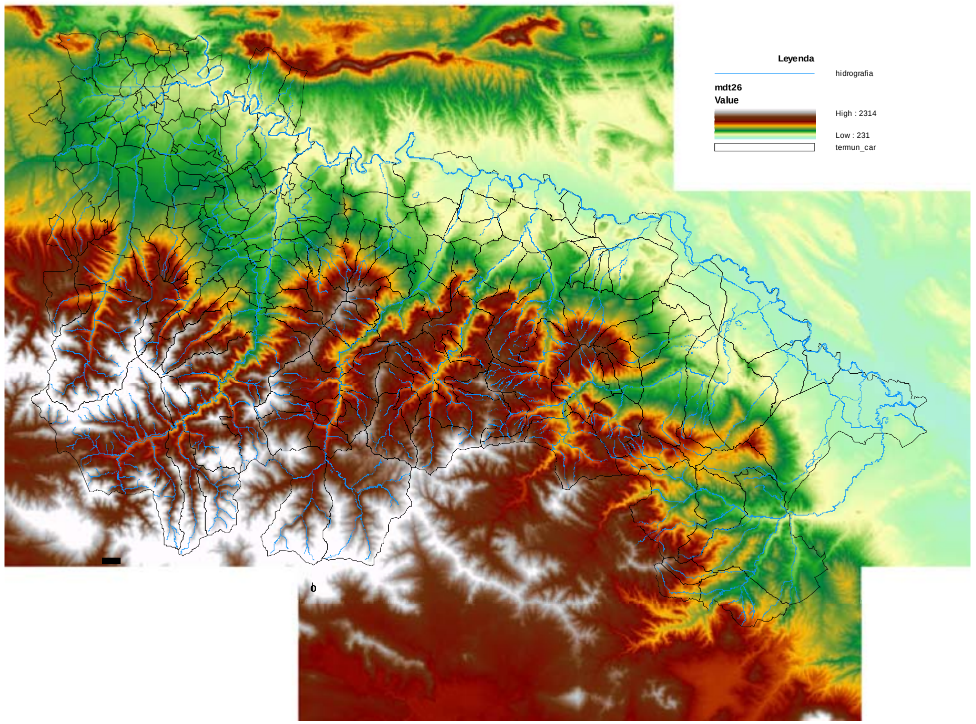


Case study: La Rioja (N Spain)

Description

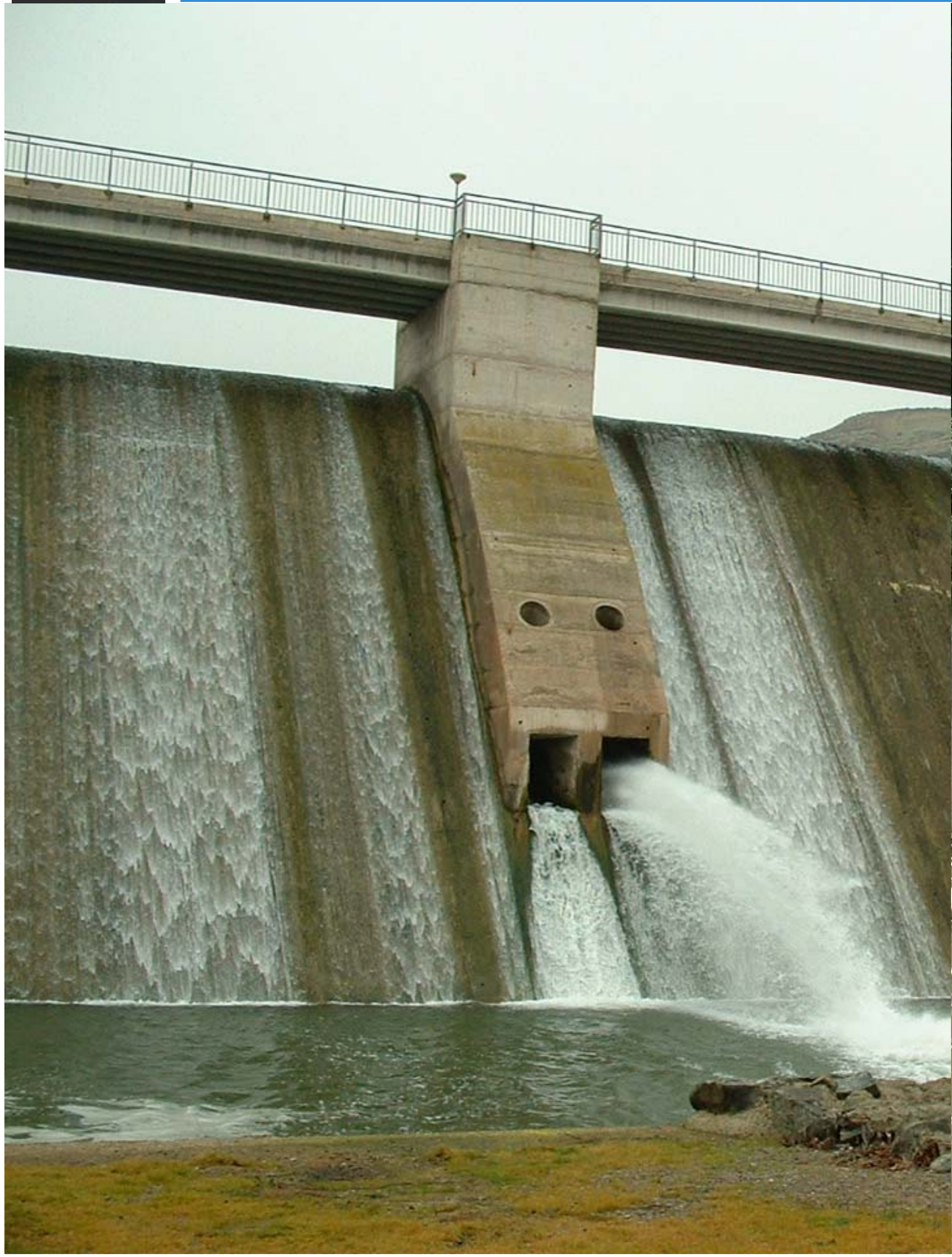






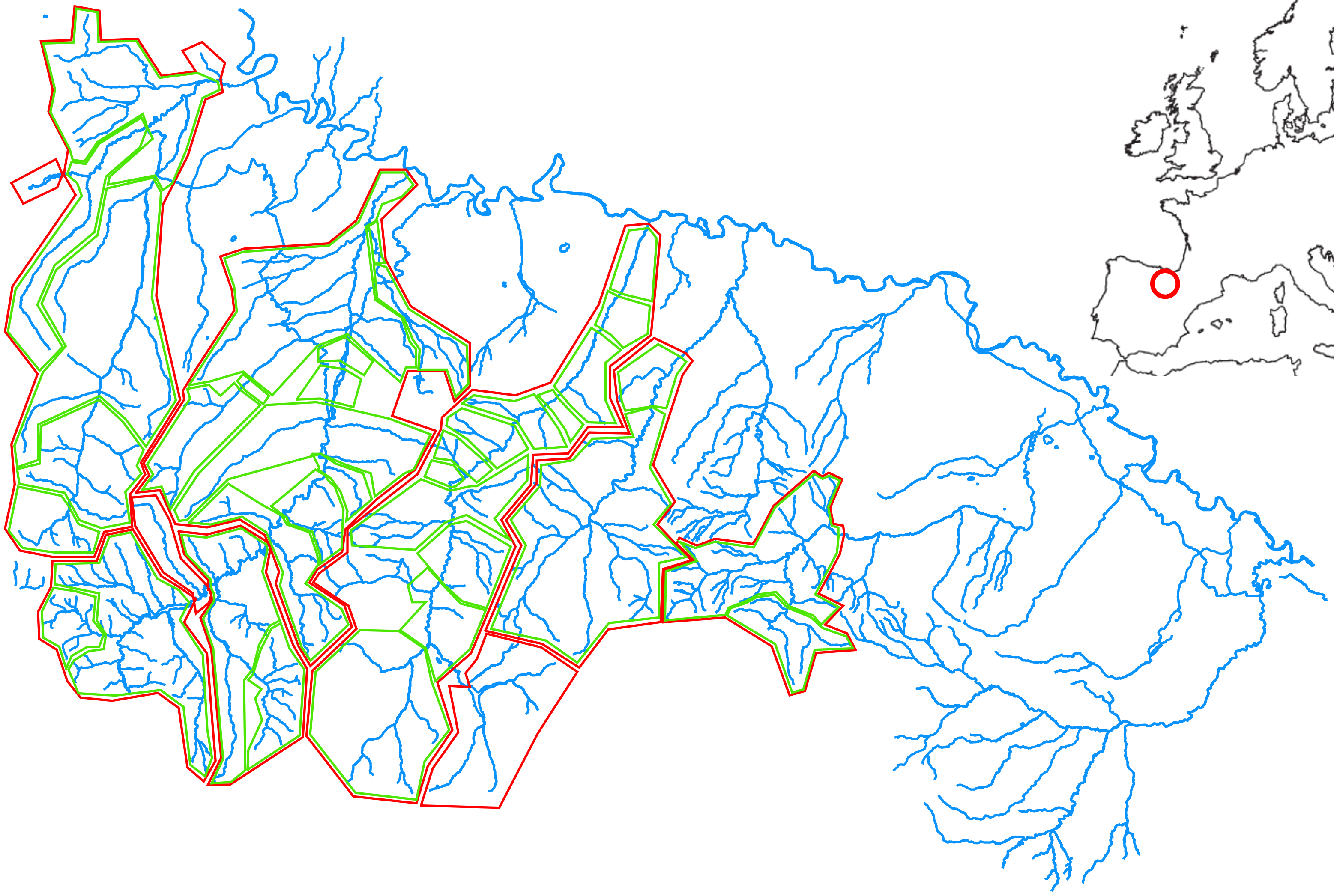
Case study: La Rioja (N Spain)

5 unpassable barriers (large dams) + 25 one way obstacles



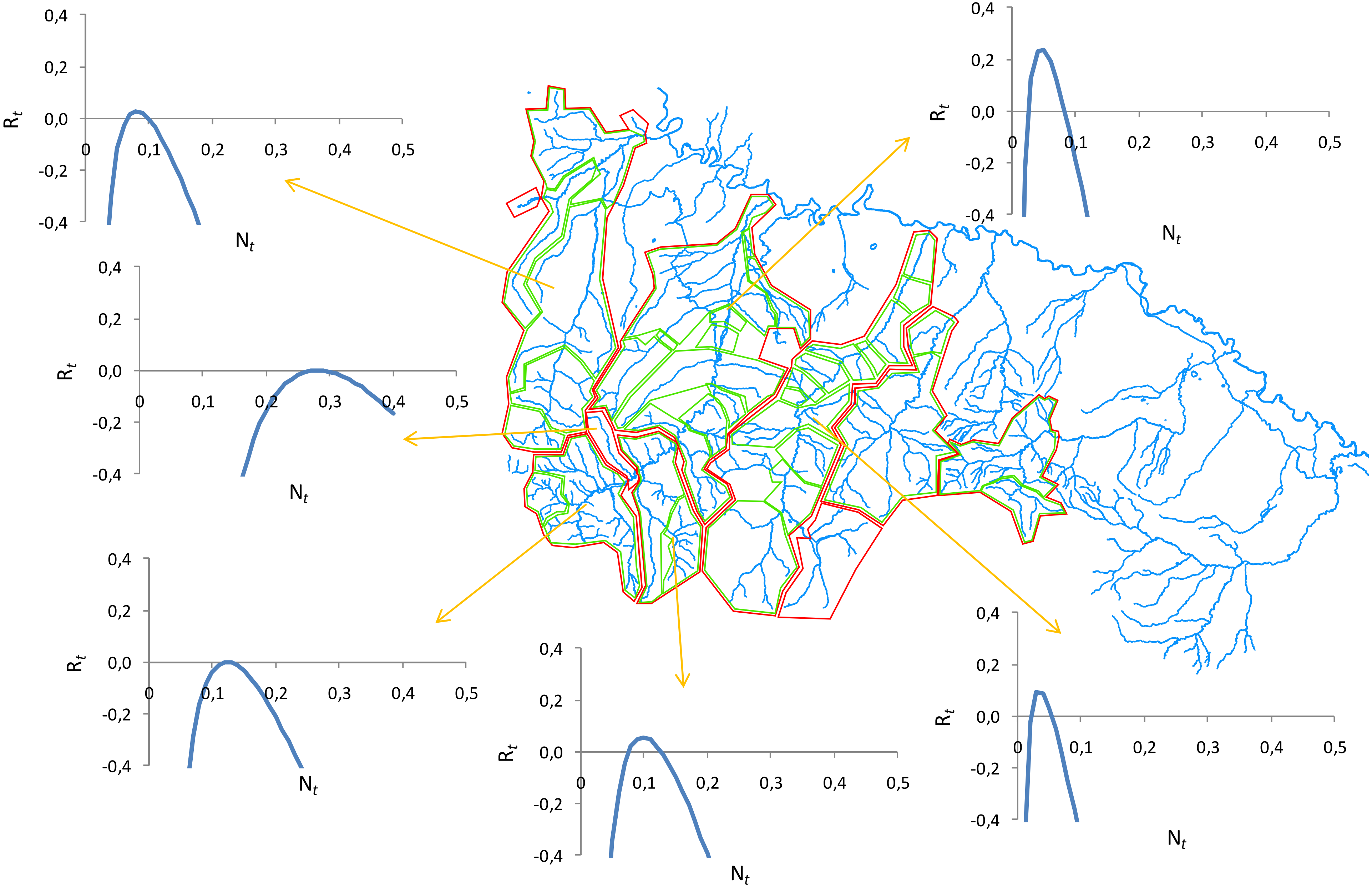
Case study: La Rioja (N Spain)

Fragment populations



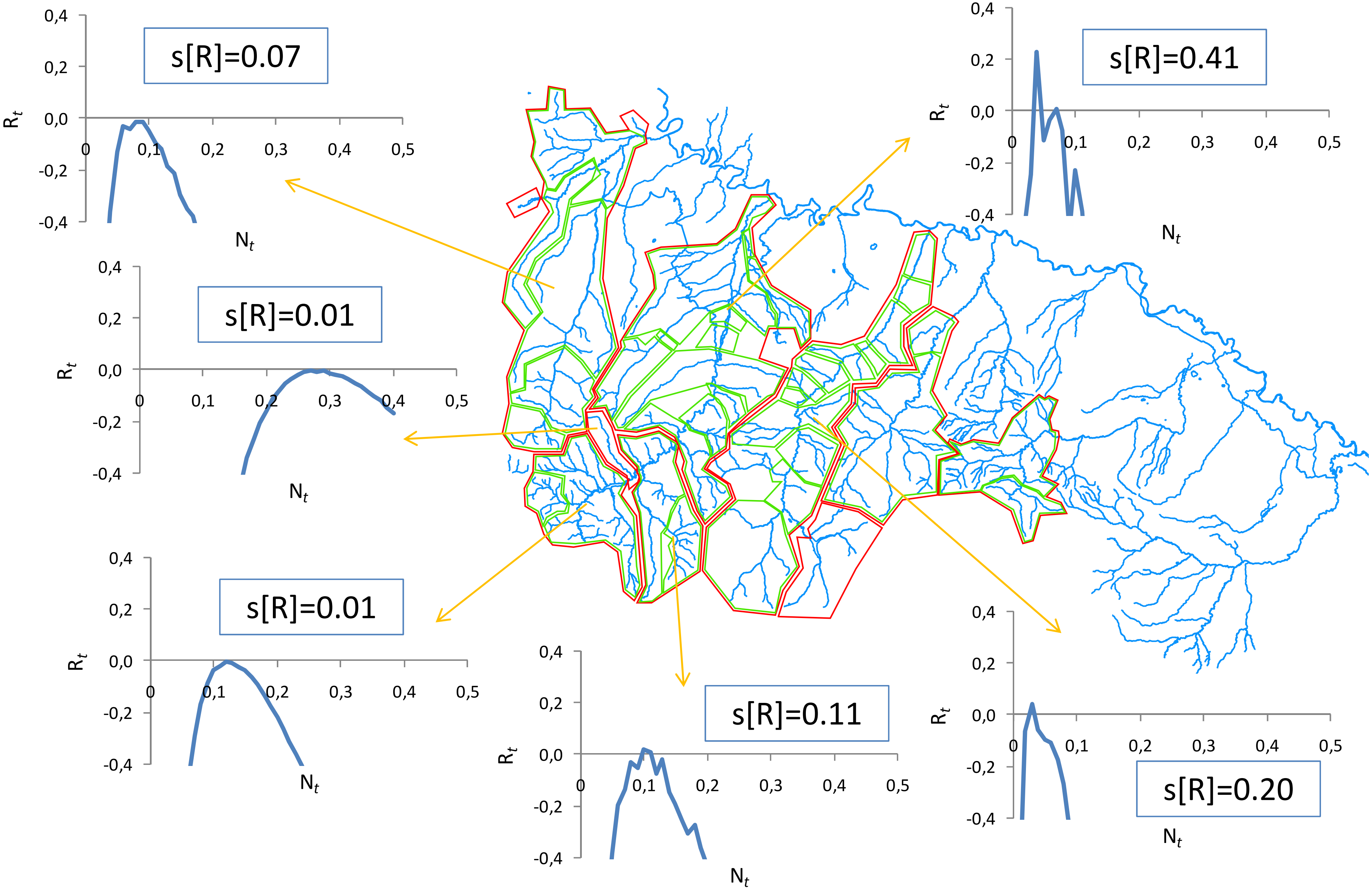
Case study: La Rioja (N Spain)

R-functions



Case study: Results

Effects of fragmentation on population dynamics



-**Population resilience (ρ)** is highly **dependent on the population resistance** (i.e. difference between carrying capacity [K] and extinction threshold [U]).

-**Extinction threshold (U)** -which mainly depends on the length of the river network inhabited by a brown trout population- is therefore **the most sensitive parameter** of the considered (logistic) population model.

-**Two way obstacles** significantly **reduce population resilience**, thus increasing small sized fragment population extinction rates.

-**One way obstacles** can theoretically **reduce resilience of non-fragmented populations** through a process induced by the most upstream population becoming small sized fragment populations.

Modeling the impact of habitat fragmentation in brown trout population

Aknowledgements

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THANK YOU FOR YOUR ATENTION

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